Exhibit A1

REPORT

FINAL REPORT

GEAE LM-5000 Turbine Blade Processing Program

To

Wagner Laser Technologies

Decatur, Illinois

January 27, 1993

Battelle
. . . Putting Technology To Work

FINAL REPORT

on

GEAE LM-5000 TURBINE BLADE PROCESSING PROGRAM

to

WAGNER LASER TECHNOLOGIES
DECATUR, ILLINOIS

January 27, 1993

BATTELLE
505 King Avenue
Columbus, Ohio 43201-2693

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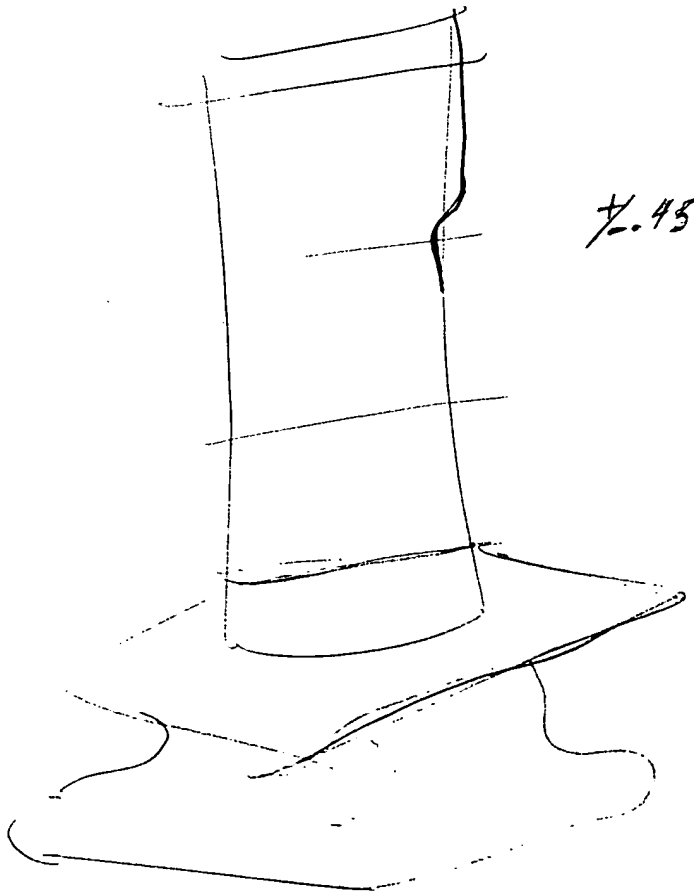

Introduction

The objective of this program was to provide GEAE with 22 laser shock processed LM-5000 stage three turbine blades. The blades were divided into three groups called test ranges. The original test matrix, as provided by GEAE, is shown below. This matrix was modified slightly with the consent of Ed Rainous of General Electric due to processing problems. The modified test matrix follows the original test plan and shows the blade numbers that were processed at each condition.

To reduce processing time, the blades were processed in groups by fluence rather than by test range. The 100 J/cm^2 fluence was processed first, followed by the 150 J/cm^2 and 200 J/cm^2 fluences, respectively. During processing of the 100 J/cm^2 fluence level, the preamplifier misfired (did not fire) several times resulting in a reduced fluence level. After the 100 J/cm^2 fluence was completed, processing was delayed until the problem was solved and no misfires occurred at the higher fluences.

Original Test Matrix for Laser Shock Processing of LM-5000 Stage 3 Turbine Blades

- Area to be shocked shall be entire leading edge only
- Spot size shall be 0.220 in. (5.6 mm)
- Shock processing shall include a 50% overlap of adjacent spots and 50% offset
- All patterns consist of one pass except for two blades identified with (*) in Test Range 2

Test Range 1: **One row with center of spot located 0.070 in. (1.77 mm) aft of leading edge**

A - two blades at 100 J/cm^2

B - two blades at 150 J/cm^2

C - two blades at 200 J/cm^2

Test Range 2: **Two rows with the center of Row 1 located on the leading edge and the center of Row 2 located 0.110 in. (2.8 mm) aft of the leading edge**

A - four blades at 100 J/cm^2

B - two blades at 150 J/cm^2

C - four blades at 200 J/cm^2

D - two blades at 200 J/cm^2 and two passes*

Test Range 3: **Three rows with the center of Row 1 located on the leading edge, the center of Row 2 located 0.055 in. (1.4 mm) aft of the leading edge and the center of Row 3 located 0.110 in. (2.8 mm) aft of the leading edge**

A - two blades at 100 J/cm^2

C - two blades at 200 J/cm^2

Final Test Matrix for LM-5000 Stage 3 Turbine Blades

Test Range 1: **One row with center of spots located 0.070 in. (1.77 mm) aft of the leading edge.**

A - blades 1 and 4 at 100 J/cm^2 with center of spots located on the leading edge

B - blades 10 and 11 at 150 J/cm^2

C - blades 14 and 15 at 200 J/cm^2

Test Range 2: **Two rows with center of the first row of spots located on the leading edge and the center of the second row located 0.110 in. (2.8 mm) aft of the leading edge.**

A - blades 3, 5, 6, 7 and 25 at 100 J/cm^2.
Blade 25 is a replacement blade.

B - blades 12 and 13 at 150 J/cm^2

C - blades 16, 17, 18 and 19 at 200 J/cm^2

D - blades 20, 21 and 24 at 200 J/cm^2, two passes.
Blade 24 is a replacement blade for blade 21.

Test Range 3: **Three rows with the first row of spots centered on the leading edge, the center of the second row located 0.055 in (1.4 mm) aft of the leading edge, and the center of the third row located 0.110 in (2.8 mm) aft of the leading edge.**

A - blades 8 and 9 at 100 J/cm^2

B - blades 22 and 23 at 200 J/cm^2

Test Range 1 Processing

Six blades were processed using a single row of 49 spots along the leading edge of the blades. Blades 1 and 4 were processed at 100 J/cm^2, blades 10 and 11 were processed at 150 J/cm^2, and blades 14 and 15 were processed at 200 J/cm^2. The spot size was nominally 5.6 mm and the spot pattern is clearly visible on the blade. Because the blades were longer than the translation stages, two co-linear translation stages were used, but only one set of coordinates could be computer controlled and recorded due to the limited capabilities of the work station. The manual stage was moved after the tenth spot location. A computer controlled rotary stage was used to keep the blade perpendicular to the beam axes. A manual stage was used to move from row to row with the aid of a dial indicator.

The blades processed at the 100 J/cm^2 fluence level were processed sequentially, starting at the squealer, with the exception of the first spot (directly on the squealer) which was applied as the tenth shot. In other words, spots 2 through 10 were applied sequentially, followed by spot 1, and then spots 11 through 49 were applied sequentially. This was done because when spot 1 was applied, the squealer geometry caused paint chipping in the spot, requiring repainting before spot 2 could be applied. By doing spot 2 first, this problem was avoided. Paint was only added if the paint flaked and exposed an unprocessed area. A positioning error occurred on this fluence level and these two blades were processed with the row of spots centered on the leading edge rather than 1.77 mm aft of the leading edge.

The blades processed at the 150 J/cm^2 and 200 J/cm^2 fluence levels were processed by hitting every fourth spot location, starting at the squealer. This required four positioning programs; however, paint was added only on an "as needed" basis.

All processing data is recorded in Appendix A. The computer automatically flags any energy meter reading that is outside of the normal operating range with a flag. All such anomalous shots are discussed in the appendix.

Test Range 2 Processing

Thirteen blades were processed using a two rows of 49 spots along the leading edge of the blades. Blades 3, 5, 6, 7, and 25 were processed at 100 J/cm^2, blades 12 and 13 were processed at 150 J/cm^2, and blades 16, 17, 18, and 19 were processed at 200 J/cm^2. Blades 20 and 21 were processed at 200 J/cm^2 with two passes. The spot size was nominally 5.6 mm and the spot pattern is clearly visible on the blade. Due to the length of the blades, two co-linear translation stages were used, but only one set of coordinates could be computer controlled and recorded due to the limited capabilities of the work station. The manual stage was moved after the tenth spot location. A computer controlled rotary stage was used to keep the blade perpendicular to the beam axes. A manual stage was used to move from row to row with the aid of a dial indicator.

The blades processed at the 100 J/cm^2 fluence level were processed sequentially, starting at the squealer, with the exception of the first spot (directly on the squealer) which was applied as the tenth shot. In other words, spots 2 through 10 were applied sequentially, followed by spot 1, and then spots 11 through 49 were applied sequentially. Paint was only added if the paint flaked and exposed an unprocessed area.

Three blades exhibited staining at the 100 J/cm^2 due to paint flaking problems. They are Blades 3, 6, and 7. Blade 25 was added to this set of blades to provide an additional unblemished blade.

The blades processed at the 150 J/cm^2 and 200 J/cm^2 fluence levels were processed by hitting every fourth spot location, starting at the squealer. This required four positioning programs; however, paint was added only on an "as needed" basis.

Blade 21 had a unique anomalous shot at spot location 6 during the second pass; water was only covering the convex side of the blade. This resulted in compressive stresses applied to only one side of the blade, warping the blade slightly. To partially compensate for

the unbalance stresses, spot 6 was reprocessed with water coverage on only the concave side of the blade, straightening it. Blade 24 was processed to replace blade 21.

All processing data is recorded in Appendix B. The computer automatically flags any energy meter reading with a flag that is outside of the normal operating range. All such anomalous shots are discussed in the Appendix.

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